GROUND WATERS INTERACTION WITH EBS FOR HLW: FROM LABORATORY TO IN-SITU SPATIAL AND TIME SCALE UP

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Simulated experiments in laboratory of the real site conditions of a DGR are used for the models of the long term performance of the EBSs. However, the scale up differences in time and space of the laboratory experiments respect to real-site is not an easy task to validate and contrast the information. This article analyses the knowledge acquired from the characterization of the FEBEX concrete plug which has been operating for 13 years in the Grimsel Test Site. During this time the concrete has interacted with granite groundwater and also with the bentonite porewater. In parallel, laboratory experiments of different sizes and age have been carried out. The spatial and temporal differences and parallelism are analysed and compared.

From the real site FEBEX 13 years experiment main alterations are characterized by low mineralogical alteration impact in bentonite that is only affected by a few millimetres. Accumulation of Mg at the bentonite side of the interface, precipitating as silicates in various forms, and heterogeneous carbonation at the interface, but mostly affecting the concrete side, have been determined at the different scales. Transport of aqueous species, being the most relevant the diffusion of chloride and sulfate from bentonite to concrete, are better observed in large scales in concrete materials. Processes determined at long term and large scale at the concrete interface are: (1) leaching of concrete with subsequent portlandite dissolution, and secondary ettringite formation, (2) progressive dissolution of C-S-H gels with incorporation of Al, and Mg and (3) friedel salt formation.

Three types of laboratory experiments were simulated. Type 1 experiments include concrete cores taken from the FEBEX plug, far from the altered zones (granite and bentonite). The cores were contacted with simulated FEBEX bentonite porewater, ponding transport tests were carried out during 6, 9 and 12 months and interaction processes were analysed. The transport of Cl, sulfates, alkalis and Mg is demonstrated. From the initial stages of interaction, the formation of new solid phases similar to those found in the Grimsel experiment, ettringite, friedel salt and calcite that extend up to 1 cm in the concrete is detected. CaO and SiO_2 from the CSH are also altered. Type 2 experiments consist of long-term (10y) concrete (CEM-I)-bentonite interaction under heat gradient (hot bentonite to cold concrete). Secondary ettringite in concrete and 1-2 mm thickness Mg accumulation was observed in bentonite, in which soluble salt migration was observed towards the heated bentonite, coupled with redistribution of exchangeable cations (Na^+ and Ca^{2+} concentrated at the concrete and Mg^{2+} and K^+ towards the hottest parts. Type 3 experiments are made of new mortar samples prepared with CEM-I and CEM-II (high pH) cement in contact with FEBEX bentonite, that have run for 4, 6 and 18 months. Their micrometric chemical profiles reproduced, in 100 µm to 1mm thickness, the characteristic elemental gradients of Mg-perturbation in the bentonite and carbonation towards the cement materials were followed. These processes of mineralogical alteration are clearly developed in 10 to 13year time scale experiments within < 5mm distance from interface.

- *Alonso et al. 2017.* Interaction processes at the concrete-bentonite interface after 13 years of FEBEX-Plug operation. Part I: Concrete alteration. Phys. Chem. of the Earth, 99: 38-48.
- *Fernández et al. 2017*. Interaction processes at the concrete-bentonite interface after 13 years of FEBEX-Plug operation. Part II: Bentonite contact, Phys. Chem. of the Earth, 99: 49-63.